12.—Petrology of the Beaconsfield Conglomerate

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Manuscript accepted—20th May, 1958

The Beaconsfield Conglomerate is made up mainly of pebbles and cobbles, most of which are derived from volcanic rock although quartzite and granite fragments also occur. Some of the more basic volcanic rocks can be matched satisfactorily with dykes (known generally by the field name of quartz dolerite) which intrude the Precambrian basement. Other volcanic rocks are spilitic, but corresponding rocks have not so far been found in the nearby Precambrian basement.

Introduction

The Beaconsfield Conglomerate is a formation in the Yandanooka Group, and is exposed in a syncline between the Mullingarra Inlier and the Darling Fault (see Fig. 1). The sequence in the group, which is of doubtful age (Late Precambrian to Silurian), has been outlined by McWhae *et al.* (1958).

(5)	Mt. Scratch Siltstone	25,000-30,000 ft
(4)	Enokurra Sandstone	680 ft
(3)	Beaconsfield Conglomerate	130 ft
(2)	Arrino Siltstone	1,670 ft
(1)	Arrowsmith Sandstone	1,100 ft

Thicknesses quoted above apply to type sections except in the case of Mt. Scratch Siltstone and the Enokurra Sandstone, where the type sections represent an incomplete thickness.

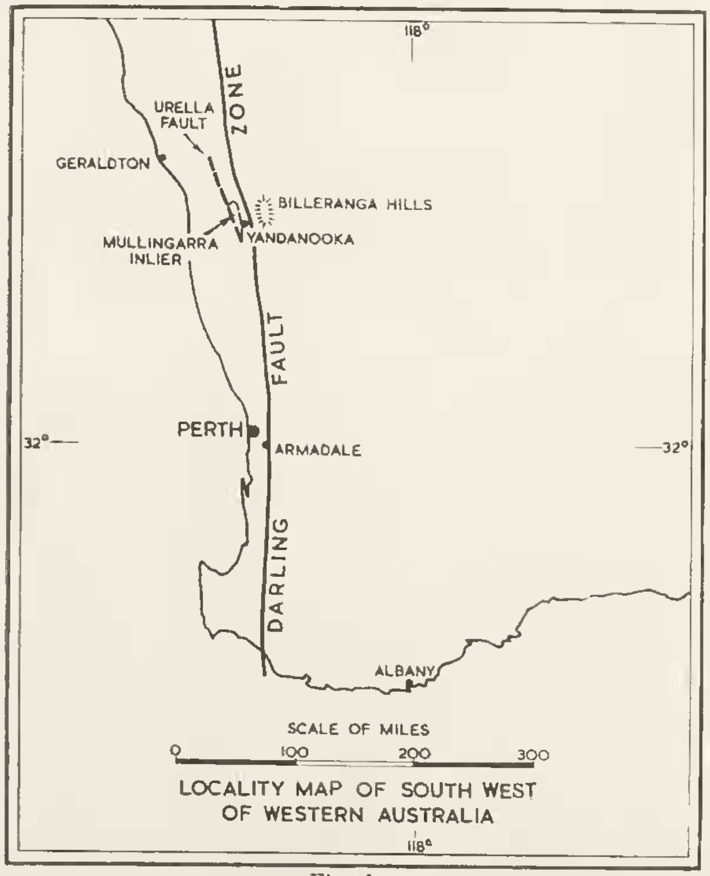

Fig. 1.

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The Beaconsfield Conglomerate is made up almost entirely of rounded pebbles and cobbles, most of which consist of volcanic rock.† All other formations in the Yandanooka Group, except the Enokurra Sandstone, contain abundant volcanic detritus, and study of their petrology logically begins with investigation of the Beaconsfield Conglomerate, where the volcanic fragments are largest and most easily identified. This paper discusses the petrography and petrology of 14 specimens from the conglomerate: twelve (36919, 38714-38722 incl., 38729, 39645) were collected by the author from an outcrop approximately 300 yards north of Granite Hill Trig., about 2 miles east-south-east of Yandanooka. Samples 32264 and Pf11 †† were kindly made available for description by the Geology Department and West Australian Petroleum Pty. Ltd., respectively. All specimen numbers, with the exception of Pf11, are those of the Geology Department of the University of Western Australia.

Petrography

General

Most specimens described here consist of individual pebbles and cobbles, and are usually stained red-brown from weathering. Many specimens are highly carbonated, and a few contain two or more pebbles cemented together by calcite. Six rock types can be recognised, namely:

(i) Spilitic lavas,
(ii) Quartz micro-diorites,
(iii) Transitional volcanic rocks,
(iv) Sandstone,
(v) Granitic fragments,
(vi) Quartzite.

Quartzite pebbles are mentioned by McWhae *et al.* (1958) and have been seen in the field by the present author, but are not described here. The other rocks are described under separate headings below.

Spilitic lavas

Four pebbles (specimens 36918, 38714, 38720, 38721) consist of porphyritic volcanic rock. Specimen 38721 (Fig. 2) is the least weathered and has been studied in most detail. It contains euhedral phenocrysts of sodic plagioclase, generally about 0.6 mm long in a fine-grained groundmass of minute plagioclase laths (mostly about 0.05 mm long), ilmenite and limonite granules and patches, and minor chlorite, epidote

† The term volcanic rock is used to denote extrusive rocks and their intrusive equivalents where these cannot be distinguished.

†† Specimen number assigned by West Australian Petroleum Pty. Ltd.

and quartz. Irregularly shaped patches of calcite, chlorite and quartz are scattered throughout and seem to have filled vesicles. Some of the quartz contains minute apatite needles. Specimens 36918, 38714 and 38720 are similar, but amygdales of chlorite are more prominent, and rutile is a common accessory.

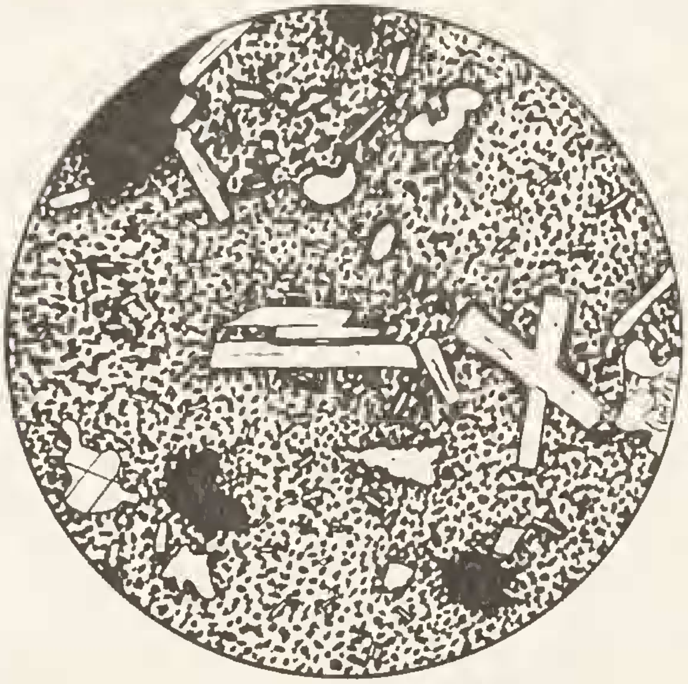


Fig. 2.—Spilitic lava (specimen 38721) showing phenocrysts of sodic plagioclase in a fine-grained groundmass of minute plagioclase grains and abundant iron ore. Amygdales consist of calcite (lower left), intergrown quartz and chlorite (centre right) and quartz. Diameter of field, 2 mm.

Plagioclase phenocrysts in specimen 38721 have a poorly developed preferred orientation, are altered locally to calcite and chlorite, and less commonly, to clay minerals and epidote. Where (001) cleavage is visible, extinction angles in sections perpendicular to *a* are negative, and the plagioclase is therefore more sodic than intermediate oligoclase. Optical data from four grains investigated with the universal stage depart notably from curves based on the standard data of Duparc, Reinhard and Nikitin, presented by Turner (1947). When several curves are used to check the composition of a grain, estimates from the various curves are likely to vary considerably (by up to 10%). Average composition of the plagioclase suggested by approximation from the curves is in the albite range. $2V_\gamma$ for three of the grains is 88° (measured in one subindividual), 88°, 89° (two subindividuals), 90°, 90°, 92° (three subindividuals). Cloudiness of phenocrysts from alteration hinders precise determination of refractive indices, but the most common value for N_β is 1.537 ± .001, indicating An_{15} — An_{19} (Winchell, 1946, p. 338). Readings as low as 1.532 ± .001 (An_7 — An_{11}) have been noted for a few grains, but in general the composition indicated from refractive indices is more calcic than that indicated by universal-stage methods. Faint normal zoning can be seen in a few phenocrysts but it is nowhere important.

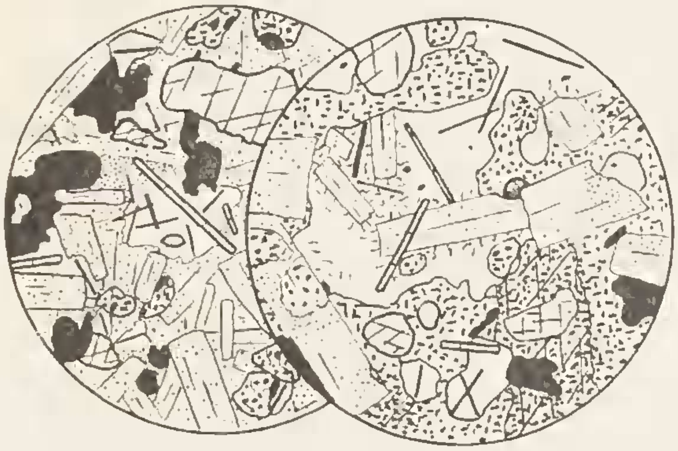
Measurements with the universal-stage were made, as far as possible, on unaltered patches in the grains. Experimental error seems inadequate to explain completely the discrepancies between optical data and the curves presented by Turner. The discrepancies probably arise partly from the method of construction of the standard curves, as according to Köhler (1949, p. 593), they were based on the optics of plutonic (low temperature) plagioclases, and do not apply closely to plagioclase from volcanic rocks. There seem, moreover, to be compositional differences between adjacent lamellae in some plagioclase grains, as observed elsewhere by Bradley (1953, p. 228) and others. It is proposed only to note the anomalies and their probable causes here, for the weathering and deuteric alteration of the rocks prevents presentation of precise chemical and optical data.

Similar anomalous optics and the same range in 2V were noted in five carefully measured phenocrysts from specimens 36918, 38714, and 38720. The composition of all the phenocrysts is, therefore, thought to be comparable, and from the refractive index determinations in specimen 38721 it lies mainly in the range of sodic oligoclase. Carlsbad, albite, Carlsbad-albite and pericline twins are present in phenocrysts in all specimens, and one occurrence of either the Manebach-Acline or the optically indistinguishable Ala A law, was observed in specimen 38720. Phenocrysts with numerous subindividuals are not common, and many grains contain only three or four subindividuals: a few with Carlsbad twins show only two. It is not unusual for two phenocrysts to form penetration twins.

The porphyritic texture, rough flow banding of phenocrysts and presence of amygdales strongly indicate extrusive origin. The rocks are referred to as spilitic lavas from their association of sodic oligoclase phenocrysts with an iron-rich groundmass.

Quartz micro-diorites

Five specimens (32264, 38717, 38718, 38722, 38724) represent the quartz diorite suite. Specimen 38718 (Fig. 3A) illustrates their mineralogy and texture. It is a weathered, even-grained to slightly porphyritic, holocrystalline hypabyssal or extrusive rock, with an average grain-size of less than 1 mm. It contains plagioclase laths, aggregates of ilmenite, limonite and haematite, clots of yellow-green chlorite, patches and veins of calcite and minor epidote. Interstitial quartz is fairly abundant, and together with K-feldspar, probably represents the end stage of crystallization. Both quartz and K-feldspar are penetrated by numerous colourless rods and needles of apatite. Plagioclase laths are generally about 0.5 mm long, have no obvious preferred orientation, and are mostly twinned on the Carlsbad, albite, and Carlsbad-albite laws. Almost all grains are at least partly altered to sericite, chlorite and calcite. The core of one of the larger and hence most calcic grains was estimated as An_{54} from standard curves, and $2V_\gamma = 73°$. Most plagioclase shows normal zoning from andesine to calcic oligoclase, and many smaller grains contain needles of apatite. Some plagioclase is partly ringed by pale brown, kaolinized K-feldspar, which separates it from patches of interstitial quartz. A little of the black iron ore is likely to be primary, but many aggregates of chlorite, limonite and black iron ore have almost certainly replaced other ferromagnesian minerals, partly by pneumatolysis and partly during weathering. These aggregates are penetrated in ophitic and sub-ophitic fashion by plagioclase.



A B

Fig. 3 (A).—Quartz micro-diorite (specimen 38718) showing iron ore (black), plagioclase (lightly stippled), chlorite (heavily stippled), K-feldspar (closely stippled), calcite (with narrow intersecting twin lamellae) and quartz (colourless). Apatite is present as rods and needles. Diameter of field, 2 mm.

(B.).—Dyke rock from Billeranga Hills (specimen 39644) showing iron ore (black), plagioclase (stippled), chlorite (heavily stippled), and calcite (with narrow intersecting twin lamellae). At lower right, amphibole (heavily stippled, with cleavage) contains a core of augite. Note also the epidote grain at right centre with high relief, the apatite rods, and the micrographic texture of some quartz. Diameter of field, 2 mm.

It is not known whether the rock is hypabyssal or extrusive, and it is therefore named only from its mineralogy, texture and grain-size. Changes caused by pneumatolysis and weathering present additional difficulty in classification. According to the classification of Hatch, Wells and Wells (1956), the rock can be regarded as transitional between quartz micro-gabbro and quartz micro-diorite.

Specimens 38717, 38722, 38724 are similar mineralogically and texturally, but their plagioclase is generally more sodic, and ranges from sodic andesine to sodic oligoclase. Specimen 32264 is porphyritic with apparent flow alignment of andesine phenocrysts and amygdales of calcite and chlorite. It has been described by Baker (1951, pp. 60-62) as an andesite (i.e. a fine-grained micro-diorite).

It is appropriate here to compare the above rocks with the basic dyke rocks which transect basement in the area. Specimen 39644 (Fig. 3B) is from a dyke cutting the Billeranga Beds near the 1,223 ft Trig. Station (about 20 miles due east of Yandanooka). The fresh rock is dark grey-green with subophitic texture, and contains pyroxene, plagioclase laths, skeletal black iron ore, abundant quartz and minor pyrite, epidote and K-feldspar. Pyroxene is pale brown with $2V_\gamma$ close to 56° and $Z\wedge c$ about 44°, and has green chlorite, green-brown hornblende, tremolite and, locally, biotite moulded on it. Measurement of the core of one plagioclase grain indicated An_{36} from standard curves, and $2V_\gamma = 88°$. Plagioclase is commonly zoned from andesine to oligoclase. Some grains are water clear, but many are converted almost wholly to sericitic aggregates. K-feldspar and quartz have micrographic texture in many places, are locally penetrated by acicular tremolite and contain abundant apatite rods and needles, some up to 2 mm long. Granules of epidote are scattered throughout. Texture and mineralogy therefore indicate quartz micro-diorite.

The five weathered pebbles from the Beaconsfield Conglomerate described above resemble strongly the rocks from the intrusive, and it is reasonable to assume that they were comagmatic.

Transitional volcanic rocks

Four specimens (Pf 11, 38715, 38719, 39645) contain highly sodic plagioclase but are different texturally from the spilitic lavas described above. Specimen 39645 is an amygdaloidal porphyritic and spilitic rock with phenocrysts of sodic oligoclase in a groundmass coarser than that of the spilitic lavas. The groundmass contains abundant pale green chlorite, minute plagioclase laths, iron ore granules and quartz. Specimen Pf 11, although porphyritic and spilitic, also has a coarser grained groundmass than the spilitic lavas. Specimens 38715, 38719 are even-grained to slightly porphyritic and their texture resembles that of most of the pebbles of micro-diorite. They are in places converted almost entirely to carbonate, but most of their plagioclase, where relatively unaltered, is clearly more sodic than that of the more typical micro-diorites, and approaches in composition that of the spilites.

Sandstone

Specimen 38716 is a sandstone consisting mainly of well-sorted, highly angular to moderately well-rounded quartz grains in a finely divided, pale brown matrix (see Fig 4). Most quartz grains range in diameter between

Fig. 4.—Sandstone (specimen 38716) showing feldspar grains (stippled, with cleavage), volcanic fragments (dark) and quartz grains (clear) in an abundant matrix. Diameter of field, 2 mm.

0.05 and 0.1 mm: a few have ragged boundaries where corroded by the matrix. Numerous rutile needles are evident in some quartz grains. Other important constituents of the sandstone are irregularly shaped, red-brown, volcanic fragments; fresh, clear oligoclase; microcline and microcline micro-perthite; and cloudy, kaolinized orthoclase. Incipient crystals and devitrified shards can be identified in many volcanic fragments which are assumed therefore to be of tuffaceous origin. Some volcanic fragments contain minute micro-phenocrysts of feldspar in a brown, iron-stained groundmass, and these fragments may have been derived from flows. Other red-brown opaque grains, some well-rounded, may also be volcanic, but their origin is uncertain. Most of the matrix is opaque and brown from iron staining, but where translucent it consists of pale brown felsic material, part of which may be fine ash. Indeterminate, elongate, cryptocrystalline fragments in the matrix have been tentatively identified as devitrified glass shards. Minor constituents include muscovite, garnet and composite quartz-chlorite grains.

Approximate composition of the sandstone is:

	%
Quartz	37
Volcanic fragments	15
Feldspar	10
Matrix	37
Other minerals	1

Precise classification of the sandstone is not possible. It has been derived from a terrain containing granitic and meta-sedimentary rocks, tuffs, and probably flows. If the abundant matrix contains altered ashy material from contemporaneous pyroclastic activity, the rock is a tuffaceous sandstone: otherwise it should be classified, following Pettijohn (1957, p. 291) as lithic greywacke.

Granitic fragments

Coarse angular fragments of quartz, microcline and microcline micro-perthite are present in the cacite matrix cementing volcanic pebbles in specimen 38714.

Origin of the Beaconsfield Conglomerate

The Beaconsfield Conglomerate is underlain by a thick sequence of fine-grained sediments containing epiclastic volcanic detritus (the Arrino Siltstone), and the abrupt change to conglomerate may have followed sudden elevation of the area being eroded. That area, at the time of Beaconsfield deposition, consisted mainly of volcanic rocks, with subordinate granitic and sedimentary rocks. It is likely, in view of the considerable extent and thickness of the Beaconsfield Conglomerate, that most of the volcanic rocks were extrusive, and that they formed a wide-spread blanket over the area. Late Precambrian or early Palaeozoic quartz dolerite intrusives have been widely recognised in sediments in the Perth Basin, and in exposures of basement rock in its northern part, but no rocks from the flows presumed to have been fed by the intrusives have so far been recognised. The dyke rock from the Billeranga Hills discussed in this paper is more sodic than the quartz dolerites, and extrusives of the more sodic suite may be represented by some of the pebbles and cobbles (quartz micro-diorites) in the Beaconsfield Conglomerate. Textures in some of the quartz micro-diorite pebbles are consistent with the hypothesis of extrusive origin.

No representatives of the spilitic rocks have so far been recognized from the Precambrian basement in the area. It is notable that some spilitic pebbles differ texturally from the lavas and range through porphyritic rocks with coarse groundmasses to even-grained rocks whose textures are similar to those of the micro-diorites. There are several possibilities regarding the origin of the spilites. They may have come from a spilitic magma, they may be differentiates of the same parent magma as the micro-diorites, or they may be products of special conditions (such as soda-metasomatism from sea-water or other sources). It is impossible to establish satisfactorily their petrogenetic relationships from such an assemblage of pebbles and cobbles which may have had diverse origins. It may be significant that the Cardup Shale, near Perth, is intruded by basic and spilitic rocks, for the Cardup Shale is considered to be of the same approximate age and in the same tectonic position as the Billeranga Beds. The basic rocks (quartz dolerites) form dykes, and the spilitic rock (chlorite-albite epidiorite) is in the form either of a large sill, or a flow. The epidiorite shows a similar range in texture to the spilitic rocks from the Beaconsfield Conglomerate, for it is locally highly porphyritic, and elsewhere is more or less even-grained. Prider (1941, p. 44) considers that the quartz dolerites belong to a later period of intrusion that the chlorite-albite epidiorite. Little more can be done toward elucidating the origin of the spilites in the Beaconsfield Conglomerate without careful search for comparable rocks in the nearby Precambrian basement.

No adequate detailed explanation can be offered at present for the virtual absence of volcanic material in the overlying Enokurra Sandstone, though it clearly indicates an abrupt and marked change of provenance.

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